Chapter 9 The age of The Mona Complex

Thew evidence that is now available upon this important question falls under two heads: first, the relations of the Complex to rocks of Ordovician age; and second, its relations to rocks of Cambrian age. On the second question, the evidence from Anglesey itself is indirect, and direct evidence- has to be sought on the mainland of Wales.

Relations of the complex to Ordovician rocks

It will be shown in Chapters 13, 14 that the zone of *Didyntograptus extensus* is clearly developed in those parts of the Island that lie to the south of the Carmel Head thrust-plane. Along the Menai Strait and thence to Llanddona the base of that zone rests upon highly schistose Gwna Beds, with their spilitic lavas, jaspers, limestones and quartzites, as well as on the Penmynydd Zone. In Central Anglesey the same zone rests in turn upon the Gneisses, the Coedana granite with its hornfels, and the New Harbour Schists with their spilites and bedded jaspers. It crosses the Bodfardden thrust-plane, there in the act of cutting out the Church Bay Tuffs, and laps on to the Gwna Beds. Where the Extensus zone has not been actually proved at the junction, it has been proved so near that the base of the Arenig Beds must be taken to be at the same horizon. About Holland Arms that base rests upon the Gneisses and upon the Pemnynydd Zone, about Llangwyllog again on the Pemynydd Zone. At the Garn Inlier it passes, in the course of half a mile, across the edges of three members of the Complex, the Gwna Beds, the Church Bay Tuffs, and the New Harbour Schists. Ten sections lay bare the base of the Extensus zone, resting on six different divisions of the Complex. The stratigraphical evidence of unconformity is complete.

Along the northern coast, the Ordovician base is at a much higher zone, that of *Nemagraptus gracilis,* and it rests only on the Gwna Beds, but on different members of that group at different places; and at Ogo Gynfor cliff (see Chapter 14, (Figure 220), (Figure 221), and (Plate 29)) a perfect unconformable junction is exposed.

The great conglomerates at the base of the Extensus zone in Central Anglesey are entirely composed of the materials of the Complex, and the same is the case at the Garn and other inliers. The pebbles include gneiss, granite (Plate 27), hornfels, mica-schist, Church Bay Tuff (often schistose) with its wriggling delessite veinlets; the mica-schist, bedded jasper and spilite of the New Harbour Beds; and (even when the beds do not rest upon the Gwna Group) Gwna quartzite, limestone, jasper, spilite, black quartzite, and Gwna Green-schist. On the nor- thern coast the Glenkiln conglomerates are full of boulders of the quartzites and schistose grits of the local Gwna type, and contain also many of scarlet Gwna jasper. The Holyhead Quartzite and the South Stack rocks have not been found, but the drift of the material was (Chapter 13) towards Holyhead, so that they could not be expected.

All the members of the Complex represented in these pebbles are in the condition in which they exist *in situ,* with their metamorphic structures and foliation fully developed. On the northern coast some of the pebbles of schistose quartzite and phyllite lie with their foliation along the bedding, not along the cleavage, of the conglomerates. Not only so, but in the conglomerates of the Extensus zone many pebbles have been found, especially of the New Harbour Schists and their fine bedded jaspers, with the rapid folding of the Mona Complex easily visible within the limits of the pebble ((Figure 102), a, 1), *c,* from the Tywyn Trewan, *d,* from Llyn Maelog).<ref>Some of these pebbles are preserved in the Museum of the Geological Survey.</ref> The cross-corrugation has also been found. The folding of the Mona Complex is therefore Pre-Ordovician, and was completed long before the Ordovician rocks were in their turn folded. Other pebbles ((Figure 102), *e,* of gneiss with granite, from the Tywyn Trewan) contain the late planes of catamorphic shearing, running through the body of a pebble but not out into the enclosing gritty matrix, and sometimes, where a conglomerate is cleaved, truncated sharply (see p. 201) by that cleavage.

It is therefore abundantly clear that the Ordovician rocks in Anglesey rest upon those of the Mona Complex with an unconformity of the first magnitude, that the folding and anamorphism of the Complex were complete, as we see them to-day, long before Ordovician times, and that erosion had cut deeply into even the most crystalline of its known members before the basal conglomerates of the zone of *Didymograptus extensus* began to be laid down upon it.

Relations of the complex to Cambrian rocks

Such being its relations to the Ordovician, the burden of proof resting upon anyone who would assign to the Mona Complex a Cambrian age becomes (unless definitely Cambrian fossils are ever found within it<ref>The fossils (of Upper Cambrian aspect) obtained along the southern margin of the Scottish Highlands in association with jaspers and spilitic lavas have not been found in Anglesey, though Llanddwyn and other localities that offer hope of organisms have been searched.</ref>) a heavy one. For though unconformities exist in Wales both within and immediately above the Cambrian system, they are on a scale quite inadequate to represent intervals of time sufficient for the stupendous folding and regional metamorphism of the Mona Complex. Apart from such considerations as this, however, there is now no lack of evidence, direct as well as indirect.

The indirect evidence

No rocks of demonstrably Cambrian age have been found in Anglesey. But in north-west Carnarvonshire, that system faces the Aethwy Region of the Complex across an interval of less than three miles. It is 5,000 feet in thickness, and is abundantly exposed on the rugged foothills, in the slate-quarries, and on the escarpments of, the mountain-land, rising to a height of some 3,000 feet. Yet the composition of the two systems is quite different. The Cambrian rocks are, with the possible exception of some pyroclastie deposits near their base, composed entirely of mechanical sediment and are comparatively uniform: the Complex presents remarkable variety. Nowhere in the latter is anything whatever corresponding to the great mass of purple slate, some 900 feet in thickness; for the purple phyllites of the Gwna Group are thin, quite different in character, and associated with spilitic lavas. Nor has any trace been found in the whole Cambrian sequence of the rapidly changing varieties of the sequence in the Complex, particularly of the conspicuous Gwna Group with its thick limestones and white quartzites, scarlet jaspers and spilitic lavas, which is persistent over the whole of Anglesey from Carmel Head to Garth Ferry, without any sign of thinning out in the direction of the mainland. The lavas and jaspers, indeed, are markedly thickening in that direction. In short, without great changes of facies in the course of three miles, of which there is no sign whatever,<ref>There may be some northward Post-Cambrian thrusting, but the relations of the members of the Cambrian system, and the verticality of the cleavage, indicate that it cannot be on the gigantic scale that is needed to bring differing facies together.</ref> it is impossible that the Mona Complex should represent the Cambrian system of Carnarvonshire.

Noteworthy also is the fact that metamorphism in the Complex does not increase as we recede from the Cambrian frontage. Progressive anamorphism, along the Strait-side (see the one-inch map and Chapter 10), is in a direction almost at right angles to that, being west-south-west-wards. Further, as a consequence of this, the highly crystalline Penmynydd Zone, with its great glaucophane-schists, runs up as near to the Cambrian front as does any member of the Complex, and strikes almost directly at it. The disposition of the metamorphic structures is therefore quite independent of the position of the Cambrian frontage and of the strike of the Post-Cambrian cleavage.<ref>Since the present Chapter was written there has appeared the paper by Mr. Nicholas (*Quart. Journ. Geol. Soc.,* LXXI, p. 138) in which he remarks that the discovery of a great series of completely different and quite unaltered Cambrian beds in the St. Tudwal's peninsula, less than seven miles to the east [of the schistose rocks of the Lleyn,] seems to offer practically conclusive evidence that this metamorphism took place in Pre-Cambrian times'; which, he adds, goes to confirm the view that the Mona Complex of Anglesey is of the same age.</ref>

In Chapter 12 some small outliers are described which rest upon the Mona Complex. Strong reasons are given for regarding them as Pre-Ordovician, in which case they must be either Cambrian or somewhat older. The Bangor volcanic rocks at Baron Hill are riding on a thrust-plane; but, though locally sheared, they are certainly quite unaffected by the powerful deformation and considerable anamorphism which have affected the underlying Gwna schists. The Careg-onen Beds, however, lie upon their natural base, and their unconformable relations to the Complex are unquestionable; so that if they be Pre-Ordovician then the Complex is Pre-Cambrian.

Pebbles in conglomerates

Direct evidence, however, has now been obtained. After the whole of Anglesey had been surveyed in detail and the various types of rock which enter into the Mona Complex had consequently become familiar to the present writer, a search was made for fragments of that Complex in the coarser deposits that occur low down in the Cambrian series of the mainland. The conglomerates and pebbly grits of Carnarvonshire were first examined, and then those that occur among the Harlech Grits, in the great Harlech anticline. Also, before the latter was visited, Mr. T. C. Nicholas kindly lent for examination some pebbles found by him in the Upper Harlech Grits of the St. Tudwal's peninsula. Professor Lapworth and Dr. Stacey Wilson, and also Mr. Griffith J. Williams-gave much valued aid by information as to localities among the Harlech mountains, where conglomerates were known by them to occur among the grits.

The results are decisive. Twenty-two different members of the Mona Complex, belonging to five of its principal horizons, have been found as pebbles in the Cambrian conglomerates. Of the twenty-two types, twelve are foliated rocks.

They are

PENMYNYDD ZONE	Quartz or quartzite-schist
	Quartz-mica-schist, Mica-schist
	Hornblende-schist
HORNFELS (?)	
GRANITE OF COEDANA TYPE	
SOUTH STACK SERIES	Green crystalline grit, white-crusted
NEW HARBOUR BEDS	Fine green flaggy schist
GWNA GROUP	Quartzite
	Black quartzite
	Spilitic lava
	Keratophyre
	Scarlet jasper
	Jasper partly bleached
	Schistose quartzite
	Schistose grit
	Nemablastic quartz — Gwna Green-schist
	Grey siliceous schist — Gwna Green-schist
	Fine sericitic schist — Gwna Green-schist
	Chloritic sericitic schist — Gwna Green-schist
GNEISSES	Gneiss
	Albite-granite

Most of the conglomerates have suffered from cleavage, so that some care has been needed to distinguish the effects of this from the original foliation of some of the less crystalline pebbles. In some cases pebbles lie with their major axes, and their contained foliation, parallel to the 'bedding and transverse to the cleavage of the conglomerate. But even where it is otherwise, it can often be shown that their foliation is their own, by one or other of the following considerations. Pebbles of the same rock, some schistose, some not so, can be found side by side. Pebbles of hard rocks, like vein quartz and quartzite, stand with their major axes along the cleavage without the least distortion of their smooth oval erosion outline, or the least internal shearing, When their foliation is nearly parallel to the cleavage, that of different pebbles may be in slightly different directions. The schistosity of the pebble is often far greater than that of the enclosing gritty matrix, even in such rocks as hard quartz-schist. In some of the siliceous chloritic schists, their thin quartz seams are strongly nemablastic.

Pebbles with Folded Foliation — In two of the pebbles of fine siliceous Gwna Green-schist, small sharp folds of the foliation, cut by little quartz-veins that are confined to the pebbles, can be seen under the hand-lens ((Figure 102) B). A thin quartz-vein in another one is faulted in the middle of the pebble.

Horizons and localities of the conglomerates

The following table shows the horizons of the conglomerates from which they were obtained.

The Cambrian conglomerates and their pebbles

Bangor Conglomerate	Bronllwyd Grit	St. Ann's Grit	Llanberis Conglomerate	Llanberis Conglomerate	Cilan Grits Of Lleyn	Harlech Grits of Harlech Anticline	Harlech Grits Of Harlech Anticline
Gored-Y-Gith	Bethesda	Bethesda	W. Side Of Llyn Padarn	Dinas-Mawr	(Nicholas Collection)	Upper Beds	Lower Beds
—	—	—	—	—	Quartz-schist	Quartz-schist	Quartz-schist
—	—	—	—	—	Quartz-mica-schist	Quartz-mica-schist	—
—	—	—	—	—	Mica-schist	Mica-schist	—
—	—	—	—	—	Hornblende-schist	—	—
—	—	—	—	—	—	Quartz of augen	Quartz of augen
—	—	Hornfels (?)	—	—		—	Hornfels (?)
—	—	—	—	—	Granite of Coedana type	—	—
—	—	—	—	—	—	—	South Stack type
—	—	—	—	—	—	New Harbour Schist	—
Quartzite	Quartzite	Quartzite	Quartzite	Quartzite	Quartzite	Quartzite	Quartzite
—	—	—	—	—	—		Black Quartzite
—	Schistose Quartzite	Schistose Quartzite		—	—	Schistose Quartzite	Schistose Quartzite
—	—	_	—	—	—	—	Beratophyre
—	—	—		—			Spilite
—	—	Jasper	Jasper	Jasper	—	—	Jasper
—	—		—	—	—	—	Bleached Jasper
Schistose Grit	—		—	—			—
Nemablastic Gwna	—	Nemablastic Gwna	—	—		Nemablastic Gwna	—
Quartz	—	Quartz	—	—	Quartz		—
Gwna Green-schist	—	Gwna Green-schist	—	—	—		—
—	—	Fine Sericitic Schist	—	—	—	—	—
—	—	—	Grey Phyllite	Grey Phyllite	—	—	—
—	—	Fragmental Albite	—	—	—	—	Fragmental Albite
—	—	Albite-Granite	—	—	—	Granite	Albite-Granite
—	—	—	—	—	Gneiss	—	Gneiss

The position of the Bangor conglomerate is still matter of discussion. That on the south-west side of Llyn Padarn was considered by Blake to lie unconformably above the Purple Slates, but as he correlated it with the Bronllwyd Grit which undoubtedly underlies the Lingula Flags, he still placed it in the Cambrian system. The other Carnarvonshire beds here quoted are admitted on all hands to lie beneath the Purple Slates of the great quarries. And the position of the Harlech Grits needs no discussion here. The pebbles from their upper beds (Barmouth Grits of Lapworth and Wilson) were obtained along the ridges from Barmouth to the crags that overlook Llyn Irddyn. Those from their lower beds (Rhinog

Grits of L. and W.) from Trawsfynydd, from the eastern limb of the anticline near Y-gelli-goch, and from the escarpments and summits of the Ithinog line of mountains, on Llethr, Ithinog-fawr, at the summit of 'The Roman Steps' (Bwlch-tyddiad), at places to the north-east of Llyn-y-morwynion, on Graig-wion, and on Y-graig-ddrwg. The place-names are taken from the one-inch maps of the Geological Survey.

Pebbles, from Llanberis and Bethesda

The conglomerates of north-western Carnarvonshire are, as is well known, composed almost entirely of debris of a quartz-felsite of that district. Pebbles from the Mona Complex are, with one exception, both rare and small, and can seldom be found until after long search among the great crowd of felsite pebbles. The exception is quartzite, which is quite abundant in some of the beds, especially at Dinas-mawr. It is of thorough Gwna type, and in the state of moderate alteration that prevails on that horizon over so much of Anglesey. A few fragments are coarse enough to be from the Holyhead Quartzite, but they have not the foliation of the only known exposures of that rock, without which it cannot safely be identified. It must be remembered that the only known outcrops of the Holyhead Quartzite and of the South Stack Series are twenty miles from Llanberis, and forty from the Ilarlech anticline. Also that they emerge from *beneath* the rest of the Complex, and were probably covered in Cambrian times. They may, however, have emerged again in the Merionethshire country.

The jaspers are absolutely typical, and cannot be mistaken. They are bright scarlet, and have all the structures of the Gwna jaspers. A pebble an inch and a quarter in length, from Dinas-mawr, has the characteristic little spherulites often seen in those from the spilitic lavas. A beautiful little pebble, a quarter of an inch across, in the St. Ann's Grit, stands out in striking contrast to the blue matrix of that rock, and has the same characters. One from Llyn Padarn is purplish in parts, like some of those from the Gwna limestones.

In the coarser parts of the St. Ann's Grit, which lies below the Purple Slates, there are small oval pebbles of siliceous Gwna Green-schist. They are finely foliated. It is in one of these ((Figure 102) B), (from the slate-quarry railway, at half a mile west-north- west of Bethesda Station) about half an inch long, which lies quite across the cleavage, that a sharp fold is visible; and in another is the thin quartz-vein that is faulted in the middle of the pebble (see p. 247). The metamorphism and all the structures of these pebbles are easily seen to have been completed before the deposition of the St. Ann's Grit.

The grey schists or gritty phyllites resemble some parts of the Gwna Beds that are free from chloritic matter, but in Anglesey such rocks (see pp. 65, 304) are rare, though they are found at the river's mouth at Carnarvon (see p. 382). Some parts of the St. Ann's Grit contain many fragments of an albite-granite that is indistinguishable from the dominant type in the Gneisses of the Complex, and granitoid pebbles are recorded by Prof. Bonney (in co-operation with Dr. Hicks and Miss Raisin) (*Quart. Journ. Geol. Soc.* 1884, pp. 187, 203; 1894, pp. 596, 600) from near Llanberis. The fragmental felspar is also albite.

Pebbles from the Harlech Anticline

The above-mentioned pebbles are sufficient to decide the question. But the scantiness of the material induced the present writer to search the Harlech "Grits in the Harlech anticline. For, although the base of the Cambrian system is not reached in that area, there seemed a hope of escaping, some twenty miles from Llanberis, the flood of felsite pebbles that crowd the conglomerates of the north. This proved to be the case. The conglomerates of the Harlech Grits, not being basal conglomerates, are not coarse, their pebbles rarely exceeding an inch in length, but they contain a much greater variety of material. It is unlikely that these pebbles were derived from the Anglesey portion of the Complex. The materials of the Harlech Grits are considered by Lapworth, Wilson and Nicholas to have come from regions to the east of the Harlech anticline.

Quartzite, again usually of Gwna type with a few fragments of a black quartzite like that of Gynfor, is found throughout the series. But the Holyhead Quartzite may be present, for in the Rhinog grits are fragments of a crystalline grit, white on the outside but bluish-green internally, of the type so common in the lower part of the South Stack Series. A deformed quartzite is also frequent.

But perhaps the most abundant pebble is a foliated quartz-schist, composed of granoblastic quartz, with well-formed flakes of secondary white mica (Plate 21), Fig. 5. The reconstruction is (except that in one pebble two crystals of tourmaline were found) precisely like that which is general in the Penmynydd Zone of metamorphism, affecting in that zone both the partially incorporated secondary quartz of segregation and the Gwna quartzites where they are involved in the metamorphic zone. Many of the fragments of venous quartz have the streaky character of the augen in the same zone of alteration. These rocks are found throughout, from the highest Barmouth to the lowest Rhinog grits. Mr. Nicholas records, hornblende-schist from the Cilan grits, but the pebbles are not in his collection. There can be little doubt that they are derived from the hornblende-schists of the Penmynydd Zone. The glaucophane-schist has not yet been found, nor has fragmental glaucophane been observed.<ref>Confined, in Anglesey, to the Aethwy Region, it may not have been among the sources of the Harlech Grits of Merioneth. It may yet be found in slides of Cambrian grits from Moel Tryfan or St. Tudwal's.</ref> In the Barmouth grits at Llyn Irddyn was found a pebble an inch and a half in length, of pale green schist such as is frequent in the New Harbour Beds close to the passage into them of the Church Bay Tuffs. Most striking of all the metamorphic pebbles, however, is a highly crystalline mica-schist with siliceous bands, not uncommon in the Barmouth grits, and obtained also by Mr. Nicholas in his Cilan grits. Thd quartz of the siliceous bands is in the same condition as that of the quartz-schists described above, but the foliated seams are a mica-schist indistinguishable from that of the Penmynydd Zone. The most beautiful pebble yet obtained is one of this type; two inches in length, that was found on the summit of Craig Abermaw, Barmouth. It is partly of quartz, with a folium of white mica, the flakes of which are about half a millimetre in length.

Low down in the Rhinog grits there is a green conglomerate which was found by the writer on the lower escarpments of Llethr and Rhinog-fawr, and thence as far as about half-a-mile to the north of Bwlch-tyddiad. It is well seen in the latter pass, just at the summit of the 'Roman Steps'. Most of the pebbles that weather out are of the quartz-mica-schists already noticed, but on breaking the rock it is found to be crowded with green volcanic fragments. These are the spilitic lavas, with keratophyres and albite-trachytes of closely allied types. The detached fragmental felspars are also albite. The pyroxenes of the lavas have been chloritised, and the matrix is also full of chlorite. Indeed, the green material which, finely comminuted and now partially recrystallised,<ref>See *Trans. Edin. Geol. Soc.,* 1897, Incipient Metamorphism in the Harlech Grits', by Edward Greenly.</ref> has coloured the matrix of the Harlech Grits throughout, could easily have been derived from erosion of the Mona Complex.

There are also fragments of the scarlet jaspers. One of these, a third of an inch across, from the Roman Steps', contains the minute spherulitic structures. Fragments of this type have the full jasper-scarlet and characteristic texture, and are unmistakable. But, along with them are others that are not so red, and through such, a gradation can be traced into siliceous pebbles that are but faintly tinged. It will be recalled (see p. 88) that, in the Middle Region, the jaspers of the Engan spilites are found to gradually lose their colour. These paler pebbles resemble the jaspers of a zone of bleaching. And it is possible that the grains of rose-quartz that are a feature both of the Harlech Grits and the St. Ann's Grit of Bethesda may be of the same nature. The beautiful blue opalescent quartz, however, which is also a feature of both grits, cannot be satisfactorily traced. Similar quartz occurs in the South Stack Series and the Gwna Beds, but not commonly; so the Cambrian blue quartz must be derived from some horizon that is not exposed in Anglesey.<ref>Quartz of this kind is a feature of some of the rocks of the Scottish Highlands. See 'Geology of the North-West Highlands', p. 131, &c., and 'Geology of Cowal', p.15, &c</ref> For fragments of unknown rocks are also found.

Granites of Mona types are found throughout the grits in moderate quantity. Some of the fragments found by Mr. Nicholas contain orthoclase, and are therefore probably from the Coedana suite of intrusions. A few fragments resemble the crypto-crystalline hornfels. On the ridge of Y-graig-ddrwg are pebbles that exceed an inch in length, of a coarse albite-granite poor in mica, like the granitoid component of the Gneiss (Plate 21), Fig. 4 traversed sometimes by a deformation that is older than the cleavage of the grits. Most of the detached albites, moreover, are stout crystals that must have been derived from these granites, and the detached quartz is largely of plutonic type. Finally, along with these granitic pebbles are a few of a true gneiss, very felspathic and with white mica, closely resembling that of the Middle Region of Anglesey. One is a biotite-gneiss, and its biotite is crowded with needles crossing at angles of 60°, precisely like those of the sillimanite-gneisses of the Nebo Inlier.<ref>These Cambrian pebbles are preserved in the Museum of the Geological Survey, with slides (E9737) , (E9738), (E9739), (E9740), (E9741), (E9742), (E9743), (E9744), (E9745), (E9746) , cut from them. Mr. Nicholas has also kindly presented his Cambrian pebbles to the Museum.</ref>

Review of the evidence

Such is the evidence of the Cambrian conglomerates. Before a final consideration of it, let us review the arguments on either side.

In favour of assigning to the Complex, or to any part of it, a Cambrian age, is the fact that the genera to which the fossils of the South Stack Series (see p. 150) have been referred, are well known in Cambrian deposits. All of them, however, are lowly forms, and when we consider the great range of certain genera, such as some of the brachiopoda; it will be seen that the presence of such forms, unsupported either by definite zonal genera (not to speak of zonal species) or by the stratigraphy, is quite insufficient for purposes of correlation. Of those from the South Stack Series, moreover, even the generic names must be regarded as provisional. In such a case, the palaeontology is of less weight than the stratigraphy. To attempt to elevate it into zonal evidence may blind our eyes to the discovery of a Pre-Cambrian fauna. In that connexion, too, a recent publication by Dr. Walcott may be of significance. He has described<ref>'Notes on Fossils from Limestone of Steeprock Lake, Ontario'. Appendix to Memoir No. 28, *Geol. Surv., Canada,* 1912.</ref> certain fossils under the name of *Atikokamia,* a new genus which he regards as having affinities at once to the Porifera and to the Archaeocyathinae, its mode of growth being essentially that of the latter. Theyarefrom the Steeprock Series of the Lower Huronian of Canada. That fossils such as those of the South Stack Series should range downwards from the Cambrian system is, indeed, only what might be expected.

In favour of regarding the Complex as Pre-Cambrian are the following considerations. It and the Cambrian are quite different; one is lithologically homogeneous, the other heterogeneous, even where only three miles apart. One is never more than slightly, the other often very highly anamorphic. Along the Menai Strait the metamorphic zones of the Complex and its foliation strike directly at the Cambrian. Small Pre-Ordovician outliers rest unconformably upon the Complex. Twenty-two different members of the Complex, twelve of them being foliated rocks, are found as pebbles in Cambrian deposits. Some of the foliated pebbles contain Pre-Cambrian folding, veining, and faulting.

If, therefore, the South Stack Series is to be assigned to the Olenellus zone, very cogent evidence must be required for such a thesis. For in such case an unconformity, and one of the first magnitude, must be inserted either between the zone of Paradoxides and that of Olenellus, or somewhere between the South Stack Series and the Gwna Beds. The only break, however, of which any sign has been detected, that at the base of the Skerries Group, is but slight and local, and, moreover, an accompaniment of strong volcanic action. The evidence of the pebbles in the Skerries Grits indicates (p. 166) that, at the time when those grits began to be laid down, the Gwna rocks had not been affected by any regional metamorphism. Everywhere else the Skerries and Gwna Groups are closely knit together (pp. 63–4, 159–61), drawing their materials from the same source (p. 65), while the fragments of old schists which the Skerries Group contains have been found also in the Gwna Beds, which beds themselves have yielded pebbles to the Cambrian. The stratigraphical difficulties are enormous. Zones of passage exist between all the clastic members of the Complex, and it has been found impossible to separate the Holyhead Group from the rest of the succession. That group, moreover, has been subjected to the whole of the stupendous folding of the Complex, and to the highest grade of metamorphism (that of the Gneisses only excepted) which it has undergone.<ref>There is yet another stratigraphical consideration. But as it is connected with the nature of the Sub-Ordovician floor, it will be well to postpone it to Chapter 13, which see.</ref> Further, the metamorphism of the South Stack Series is the first of the three that affect the Bedded Succession, whereas many of the metamorphic pebbles of the Cambrian are from Penmynydd and Gwna rocks reconstituted during the third episode of metamorphism, by which time the South Stack Series had not merely been deposited, but long since metamorphosed.

Conditions of the Cambrian erosion

Most of the volcanic fragments of the Rhinog grits are quite undeformed, whereas in Anglesey to-day the tracts of spilitic lava that are free from deformation are comparatively small. It would appear, therefore, that the pebbles were derived in great measure from zones of the earth crust not so low down as the zone of flowage. Such would be found on the tectonic horizons that must once have overlain the Bodorgan Fold. They would be exposed to the denuding forces much sooner, and for much longer, than the schistose rocks upon the lower folds, which would, however, begin to be exposed along with them as soon as the major secondary anticlines had been cut into. These upper folds are not found in Anglesey. They had, indeed, been swept away before even Ordovician denudation had begun, for nearly all the pebbles

in the Arenig conglomerates are schistose (Chapter 13). In early Cambrian time they still formed a large part of the ancient surface. But in the course of the great Cambrian erosion they were totally destroyed, and the deposits of that system are their sole surviving monument.

A series of geological accidents has combined in a curious way to conceal the true relations of the Mona Complex to the Cambrian. First: Arenig denudation seems to have removed such Cambrian deposits as once existed upon the tracts of the Complex that are now exposed to view.<ref>See the paper by Mr. Nicholas, already cited; also Chapter 12 of this work.</ref> Next: The Cambrian material came chiefly from folds higher than the Bodorgan Fold, upon which the rocks were undeformed; and at the same time those folds were totally destroyed by the Cambrian denudation. Thirdly: About Llanberis, at the close of Pre-Cambrian time, an acid lava was poured out upon the slopes of the old land, covering it with a shield upon which the forces of Cambrian erosion were obliged, locally, to spend themselves.<ref>This may account for the failure to find glaucophane in any of the Cambrian sediments.</ref> It would seem, however, that on those old slopes there were hills of quartzite, round about which the lava flowed without burying their tops, from which the conglomerates were thus able to obtain their quartzite pebbles. Further away to the south-east, wide tracts of the Complex were quite bare, the waste of which furnished the vast deposits of the Harlech Grits. Unfortunately, in those districts the Cambrian base is not exposed, so that evidence has had to be sought from beds that are hundreds, and some of them even thousands of feet up in the series. That conglomerates of such a composition could be formed at all on such horizons indicates that below the base of the Harlech Grits there must lie a coarse conglomerate like that of the Arenig Beds of Anglesey, resting upon the surface of the Mona Complex, and composed of a great variety both of undeformed and of metamorphic rocks.

Conclusion

However this may be, it is now abundantly evident that the Complex is Pre-Cambrian. And that it is Pre-Cambrian as a Complex, not its material only, but its regional metamorphism being of that date. For the pebbles include, as well as rocks that are but slightly altered, such as Gwna spilite, quartzite and jasper, the Penmynydd mica-schists and even the Gneisses, the most highly crystalline of all its members. The same rock is found among the pebbles in more than one stage of alteration. The Gwna cherts, for example, were first jasperised, and then dejasperised (see pp. 88, 166) by dynamic metamorphism, the quartz sands quartzitised and then deformed, in Pre-Cambrian times. Foliation, often accompanied by a high grade of crystallisation, was induced, and the rocks became crystalline schists. The foliation was very sharply folded, then it was fissured and cut by veins of quartz, and these again cut by later faults; all before the lowest beds of the Cambrian system were deposited. No subsequent alterations have produced any perceptible effects. In the Ordovician conglomerates we find the rocks of the Mona Complex in the condition in which they are to-day. In the Cambrian conglomerates we find them just as they are in the Ordovician conglomerates.

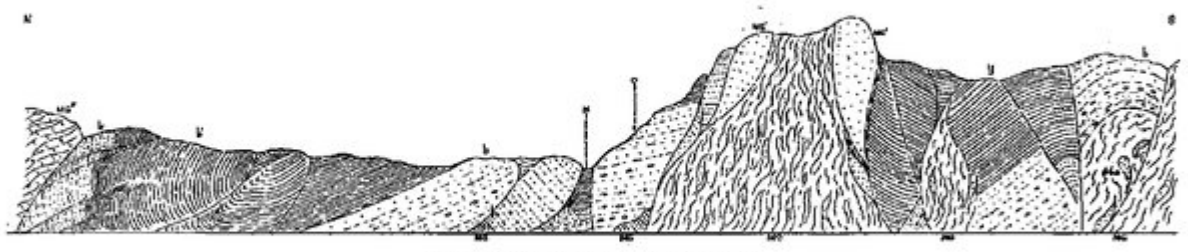


Fig. 220.—Cliff Section at Ogof Gynfor.
Drawn from a boat, and brought to one plane. Scale about 65 feet = one inch.
MG = Gwna mélange. MG' = Gwna quartzite. Mg' = Gwna limestone. b = Glenkiln conglomerate. b' = Cherty shales.
Graptolites (A.f. 3507–22) obtained from base of shales below X. Unconformable base (see Plate XXIX and Fig. 221) well seen at cliff's foot below O.

(Figure 220) Cliff section at Ogof Gynfor. Drawn from a boat, and brought to one plane. Scale about 65 feet = one inch. MG = Gwna mélange. MG■ = Gwna quartzite. Mg■ = Gwna limestone. b = Glenkiln conglomerate. b■ = cherty shales. Graptolites [a.f. 3507-22] obtained from base of shales below X. Unconformable base (see (Plate 29) and (Figure 221))

well seen at cliff's foot below O.

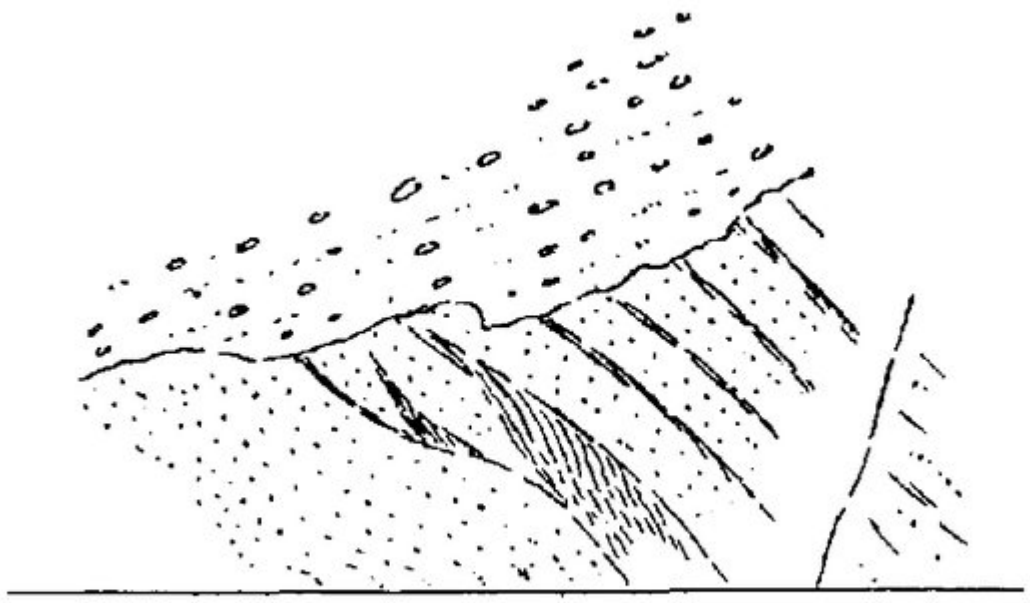
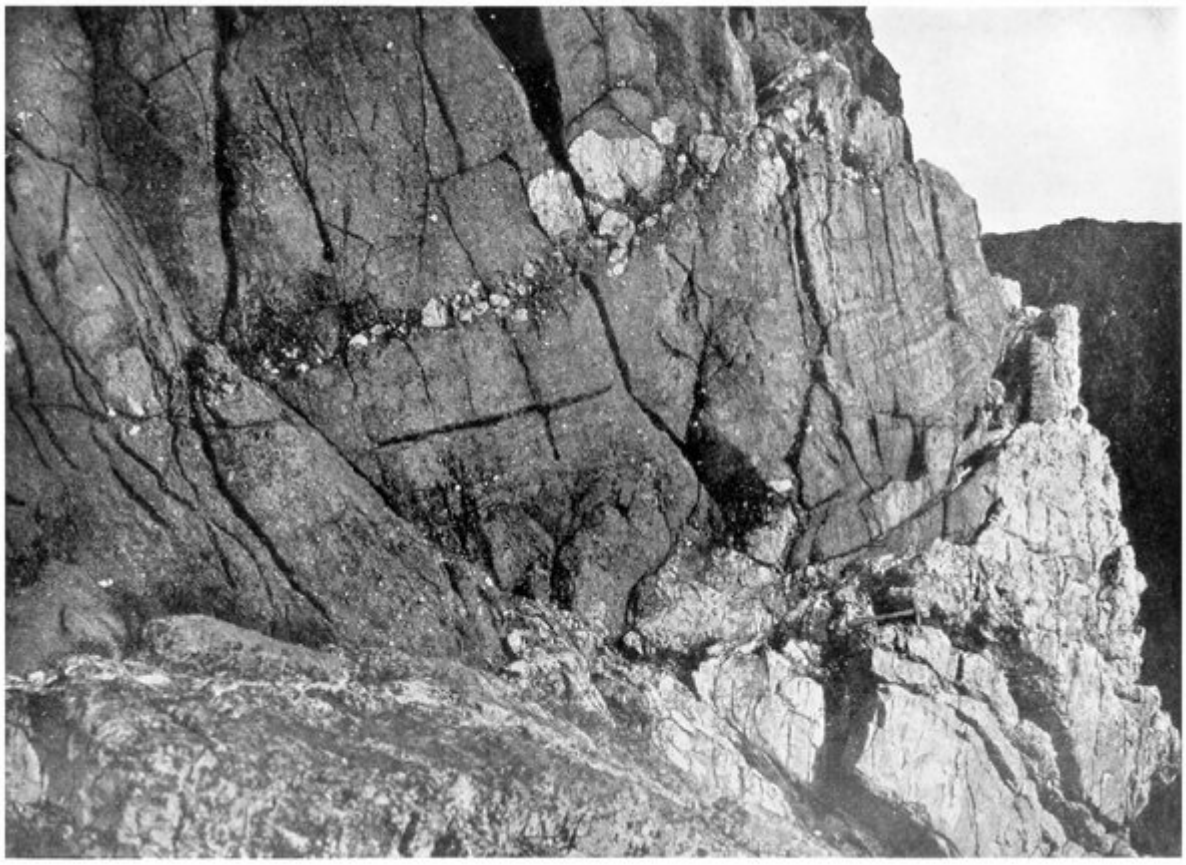


FIG. 221.—THE UNCONFORMABLE JUNCTION OF PLATE XXIX.

(Figure 221) The unconformable junction of (Plate 29).



(Plate 29) Glenkiln conglomerate resting unconformably upon the Mona Complex. Ogo Gynfor.

(Plate 27) Granitoid boulder from the Mona Complex in Arenig basement conglomerate. Tywyn Trewan.

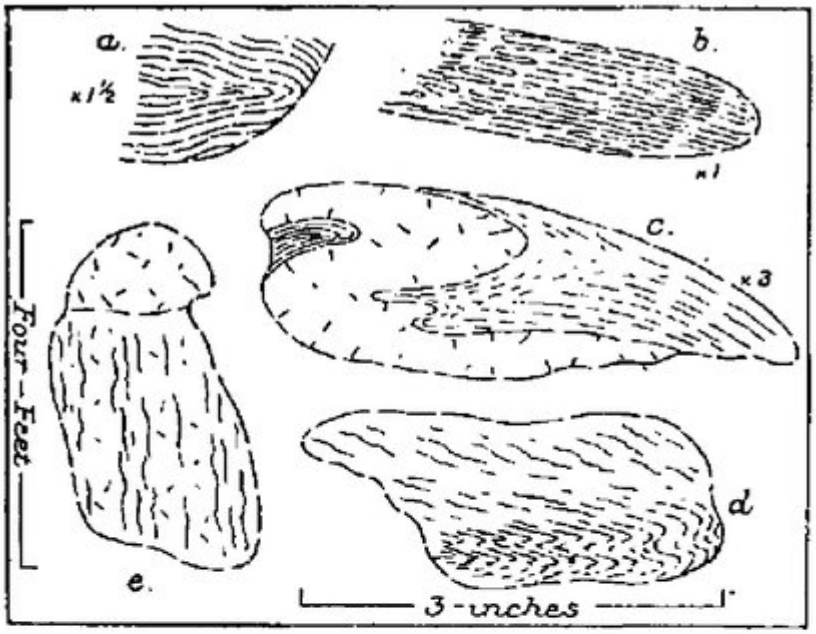


FIG. 102.

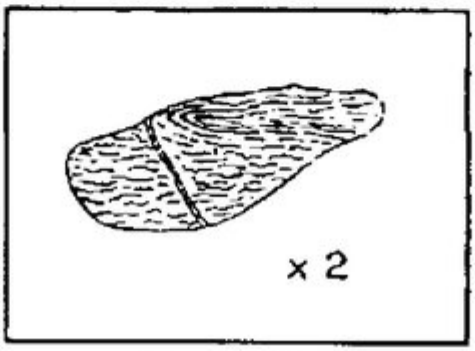
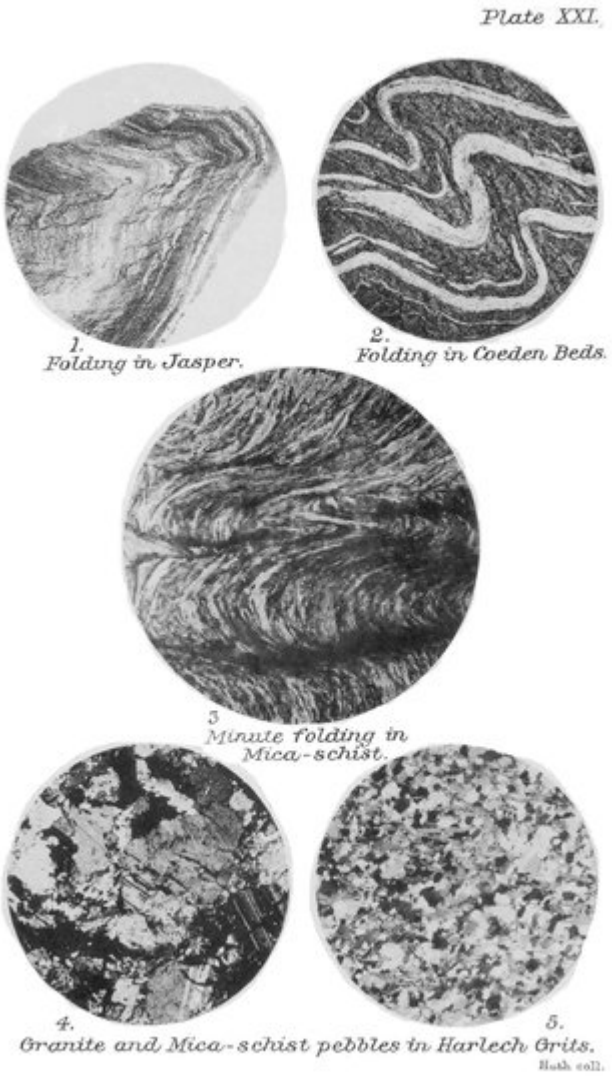


FIG. 102 B.

(Figure 102) Pebbles from the basal Arenig conglomerates Containing old folds and thrusts of the Mona Complex. 102 B. Pebble from Lower Cambrian Grits containing an old fold and vein of the Mona Complex.



(Plate 21) Microphotographs of the Mona Complex. 1. Folding in Jasper. 2. Folding in Coeden Beds. 3. Minute Folding in Mica-schist. 4. Granite Pebble in the Harlech Grits. 5. Mica-schist Pebble in the Harlech Grits. See Appendix 3.